

Root growth potential and seedling morphological attributes of narra (*Pterocarpus indicus* Willd.) transplants

R.M. Gazal^{a,*}, C.A. Blanche^b, W.M. Carandang^c

^aDepartment of Renewable Resources, University of Wyoming, 1000 E. University Avenue, Laramie, WY 82071, USA

^bUSDA CSREES Natural Resources and Environment, Washington, DC 20250, USA

^cCollege of Forestry and Natural Resources, Institute of Renewable Natural Resources, Laguna 4031, Philippines

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Abstract

The lack of simple and reliable nursery grading practice to assess quality of planting stocks led to the failure of many reforestation projects in the Philippines. Thus, it is important to develop a mechanism to evaluate nursery seedling quality and performance prior to field planting. The study was conducted to evaluate two measures of root growth potential (RGP; number and length of new roots) as seedling performance attributes of narra (*Pterocarpus indicus* Willd.), one of the most valuable native reforestation species in the Philippines. RGP was determined in response to three different soil moisture regimes (50, 75 and 100% of field capacity). Effects of these treatments on height, root-collar diameter, stem diameter, length of taproot, shoot biomass, root biomass, total biomass, root:shoot ratio and seedling quality index were also investigated. Measurements were made on 7, 14 and 21 days after transplanting. The experiment was laid out using a completely randomized design. RGP and length of taproot were significantly affected by moisture treatment at 7 days. High RGP and longer taproots were observed in soil at 50% of field capacity. Increased stem diameter, shoot biomass, total biomass and quality index were observed in the reduced soil moisture condition at 7 and 14 days. Results confirm that narra is capable of producing new roots in response to reduced soil moisture on a relatively short period of time. This response would enable narra plants to counteract transplanting shock thereby ensuring their survival in the nursery. Correlation analysis of new root counts and length measurements revealed a strong positive correlation with each other. Thus, either will provide a good estimate of RGP in narra.

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1. Introduction

Inability to recognize seedling quality as a measure of planting performance in the field has led to the failure of many reforestation and plantation projects. Strategies for assessing quality of planting stocks need

to move away from the traditional approach of looking only at the sound morphological characteristics of seedlings (Grossnickle et al., 1991). These morphological indices often fail to account for differences in seedling physiology (Gazal and Kubiske, 2004). Hence, holistic assessment of stock quality requires the integration of both morphological and physiological attributes of seedlings. Consideration of both factors provides a more effective appraisal of the fitness of seedlings for field planting.

* Corresponding author. Tel.: +1-307-766-2306;
fax: +1-307-766-6403.
E-mail address: rgazal@uwyo.edu (R.M. Gazal).

Root growth potential (RGP = root growth capacity = root regeneration potential) is a physiological attribute that can be easily measured and used to assess seedling quality. It is defined as a gauge of the ability of a seedling to produce new roots when growing in an ideal environment (Ritchie, 1984). Knowledge of the RGP and familiarity with the plant root system is key to understand ecological fundamentals that influence seedling quality (Bohm, 1979).

The ability to absorb water is an important factor affecting the establishment of tree seedlings. Increased access to soil water is highly dependent on new roots produced after planting (Burdett, 1987; Colombo and Asselstine, 1989). Hence, the optimal level of water stress to favor the root growth of tree seedlings is important in setting the standard for using RGP as an indicator of planting stock vigor.

Narra is one of the most valuable and commonly used reforestation species in the Philippines. It is propagated by seeds and cuttings but seedling stocks are mainly used for reforestation and rehabilitation of denuded land areas (Rise, 1995). Because of its high wood quality, this species is an excellent source of timber and wood material for furniture in southern Asia. Narra grows throughout the Philippines and other tropical countries such as India, Borneo, Celebes, New Guinea and the Caroline Islands (Rise, 1995). As a nitrogen fixer, narra is well adapted to low nutrient and available water conditions. The potential for using RGP as an indicator of seedling quality and performance of narra needs to be explored. Hence, this study was conducted to evaluate two measures of RGP (number and length of new roots) and provide a basis for interpreting RGP as a seedling performance attribute of narra under different levels of soil moisture.

2. Materials and methods

The study was conducted from September to November 1997 in a greenhouse at the University of the Philippines Los Baños (UPLB). Narra pods were collected from a stand located on Mount Makiling at the UPLB campus. Only mature pods from phenotypically desirable trees were collected. To facilitate germination and root formation, seeds from the pods were extracted and air-dried for a

week. No pre-germination treatment was applied to the seeds.

The soil medium used in the seed boxes was composed of an equal mixture of forest topsoil and humus from Mount Makiling. The medium used for the pots was a mixture of sand and forest topsoil with a ratio of 2:1. Mixing of soil medium from different sources (topsoil, humus and sand) was done based on volume. To remove soil-borne microorganisms from the potting medium, soil was sterilized (dry-heat) at 100 °C for 2 h.

Narra seeds were sown in 80 cm × 60 cm × 20 cm seed boxes with shallow drills 5 cm apart in September 1997. The narra germinants were grown from September to October 1997, for a period of 1.5 months before transplanting into plastic pots. The germinants had an approximate average height and stem diameter of 10.2 cm and 1.5 mm, respectively, when transplanted. During transplanting, the seedlings were carefully uprooted from the seed boxes and thoroughly washed to remove excess soil. All lateral roots were clipped off before potting to bring all the seedlings to the same starting point (DeWald and Feret, 1987). Each pot was filled with 1.5 kg of soil. The height, root-collar diameter, stem diameter at 1 cm above the root-collar and length of taproot were measured. RGP and morphological attributes of narra transplants was compared under three soil moisture regimes: soil at 50% of field capacity; soil at 75% of field capacity; soil at 100% of field capacity.

The study was laid out using a completely randomized design. A total of 180 potted narra seedlings under greenhouse conditions were randomly assigned to the three moisture level treatments. Each treatment was replicated 60 times. RGP was measured at 7, 14 and 21 days after transplanting. For each treatment, 20 seedlings were measured destructively at each test interval.

Prior to transplanting, the field capacity of the pot soil medium used was determined. Three pots were sampled for this purpose. The pots were saturated with water, covered with plastic to avoid evaporation and allowed to drain for 36 h. Soil samples from each pot were then taken for moisture content determination. The average moisture content was calculated and expressed as a percentage of field capacity.

After determining the field capacity of the soil medium, the amounts of soil moisture at 50, 75 and

100% of field capacity were calculated. Immediately after transplanting, each seedling received the corresponding amount of water, based on the calculated percentage moisture. To keep the soil water content close to the target value per moisture treatment, pots were weighed everyday and watered as required. Each pot was covered with foil and the side was wrapped with packaging tape to ensure minimal soil water loss. Cotton was also placed at the base of the stem of the seedling.

After each test period, 20 seedlings per moisture treatment were randomly selected for measurement. RGP of each seedling was measured by counting the number of new roots and measuring their lengths. Since the taproot of each seedling was devoid of any lateral roots prior to transplanting, all roots that emerged after the test period were considered new roots. Only those new roots with a length ≥ 0.5 cm were considered (Burdett, 1987) except during the 7-day test period when all new roots were measured regardless of length. The length of new roots was expressed as the total length of new roots per seedling.

Aside from RGP, the following attributes of the seedling were also measured at each test period: stem height which is the height of the seedling from the root-collar to the highest terminal bud, root-collar diameter, stem diameter at 1 cm above the root-collar and length of taproot. At the end of each test period, five seedlings in each treatment combination were sampled for biomass determination.

The seedling quality index developed by Dickson et al. (1960) was used to measure the performance of narra seedlings. Quality index was calculated as:

quality index

$$= \frac{\text{total biomass (g)}}{\text{height (cm)/stem diameter (mm)} + \text{shoot biomass (g)/root biomass (g)}} \quad (1)$$

Analysis of variance (ANOVA) was used to compare the effects of moisture levels on RGP. ANOVA was also used in comparing the difference in RGP among the three test periods (7, 14 and 21 days after transplanting). Duncan's new multiple range test was employed to determine which of the moisture levels and test periods were significantly different at $P = 0.05$. The Statistical Analysis System (SAS, Version 8) was used to analyze the data generated in the study (SAS Institute, 2002). Correlation analysis was

also performed to determine the degree of relationships between RGP parameters and other seedling morphological traits.

3. Results

Significant differences in diameter, shoot biomass, total biomass and quality index remained until the 14-day test period (Table 1). However, no significant differences in seedling morphological traits were evident at the 21-day test period (data not shown). During the 7-day test period, the number of new roots was highest in the 50 and 75% of field capacity treatments (Fig. 1a). The length of new roots was lowest in the 100% of field capacity treatment (Fig. 1b). Both root-collar and stem diameter were also significantly affected by varying moisture levels (Table 1a). Largest root-collar and stem diameter were observed at 75% of field capacity (1.88 and 1.67 mm, respectively). The 50% of field capacity treatment generated the longest taproot length of 10.3 cm. Shoot and root biomass and quality index were lowest at the 100% of field capacity treatment.

During the 14-day test period, effect of soil moisture on height, stem diameter, shoot and total biomass and quality index was significant (Table 1b). The tallest height was observed in seedlings subjected to 75% of field capacity (12.0 cm) and the shortest height at 100% of field capacity (10.1 cm). The largest diameter of 1.65 mm and highest shoot biomass of 0.17 g were achieved at 50% of field capacity. The lowest total seedling biomass of 0.14 g was observed at 100% of field capacity. It was also at 14-day test period that highest quality index value of 0.015 at 75% of field capacity was attained.

Overall, soil moisture had significant effects on height, diameter, length of taproot, shoot, root and total biomass and quality index (Fig. 2). The highest level of soil moisture (100% of field capacity) had the lowest height (10.1 cm) (Fig. 2a). This result was significantly different from the 50 and 75% field capacity treatments with heights of 11.3 cm for both. Largest stem diameter (1.6 mm) was observed at 75% of field capacity treatment (Fig. 2c). The effect on diameter was found to be significant between the 75 and 100% of field capacity treatments with the latter as the lowest. The 100% of field capacity yielded the

Table 1

Effect of soil moisture regimes (soil at 50, 75 and 100% of field capacity (FC), on morphological attributes of narra seedlings (a) 7 days and (b) 14 days after transplanting. Only means (\pm S.E.) that were statistically significant are shown

Growth parameters	Soil moisture regimes		
	50% of FC	75% of FC	100% of FC
(a) 7 days after transplanting			
Stem diameter (mm)	1.89 \pm 0.08 a	1.87 \pm 0.05 a	1.70 \pm 0.04 b
Root-collar diameter (mm)	1.57 \pm 0.05 ab	1.67 \pm 0.05 a	1.46 \pm 0.03 b
Length of taproot (cm)	10.32 \pm 0.51 a	8.49 \pm 0.87 ab	6.88 \pm 0.61 b
Shoot biomass (g)	0.14 \pm 0.01 a	0.14 \pm 0.01 a	0.10 \pm 0.01 b
Total biomass (g)	0.16 \pm 0.01 a	0.16 \pm 0.01 a	0.12 \pm 0.01 b
Quality index	0.011 \pm 0.001 ab	0.012 \pm 0.001 a	0.009 \pm 0.001 b
(b) 14 days after transplanting			
Height (cm)	11.55 \pm 0.47 a	12.03 \pm 0.51 a	10.11 \pm 0.46 b
Stem diameter (mm)	1.65 \pm 0.06 a	1.61 \pm 0.06 ab	1.52 \pm 0.05 b
Shoot biomass (g)	0.17 \pm 0.02 a	0.17 \pm 0.02 a	0.11 \pm 0.01 b
Total biomass (g)	0.20 \pm 0.02 a	0.20 \pm 0.02 a	0.13 \pm 0.02 b
Quality index	0.015 \pm 0.002 ab	0.015 \pm 0.002 a	0.01 \pm 0.002 b

In a row, means with the same letters are not significantly different at 5% level based on Duncan's new multiple range test.

shortest taproot length, lowest shoot, root and total biomass (Fig. 2d–g). The 50 and 75% of field capacity had the highest seedling quality index (Fig. 2i).

Correlation analysis revealed that all the morphological traits, except root:shoot ratio, were significantly correlated with RGP (number and length of new roots) (Table 2). A significant positive correlation was observed between number and length of new roots ($r = 0.80$).

4. Discussion

In this study, the relationship between number and length of new roots as measures of RGP behaved similarly in response to moisture regimes. Response of narra transplants to different levels of moisture can already be seen at the 7-day test period. This result suggests that narra transplants quickly respond to the limited amount of moisture as reflected in their RGP.

Table 2

Correlation of root growth potential and seedling morphological traits of narra transplants

	H	RCD	D	LTR	NR	LNR	SB	RB	RSR	TB	QI
H	1.00	0.52*	0.51*	0.49*	0.28*	0.28*	0.77*	0.65*	0.07	0.78*	0.64*
RCD		1.00	0.75*	0.41*	0.25*	0.26*	0.61*	0.51*	0.02	0.62*	0.59*
D			1.00	0.42*	0.31*	0.34*	0.65*	0.52*	−0.04	0.65*	0.64*
LTR				1.00	0.23*	0.18*	0.52*	0.54*	0.17	0.55*	0.55*
NR					1.00	0.80*	0.39*	0.38*	0.06	0.41*	0.44*
LNR						1.00	0.41*	0.43*	0.13	0.43*	0.48*
SB							1.00	0.74*	−0.06	0.99*	0.83*
RB								1.00	0.55*	0.83*	0.97*
RSR									1.00	0.07	0.39*
TB										1.00	0.90*
QI											1.00

NR = number of new roots; LNR = length of new roots; H = height; RCD = root-collar diameter; D = stem diameter; LTR = length of taproot; SB = shoot biomass; RB = root biomass; RSR = root:shoot ratio; TB = total biomass; QI = quality index.

* Significant at $P = 0.05$.

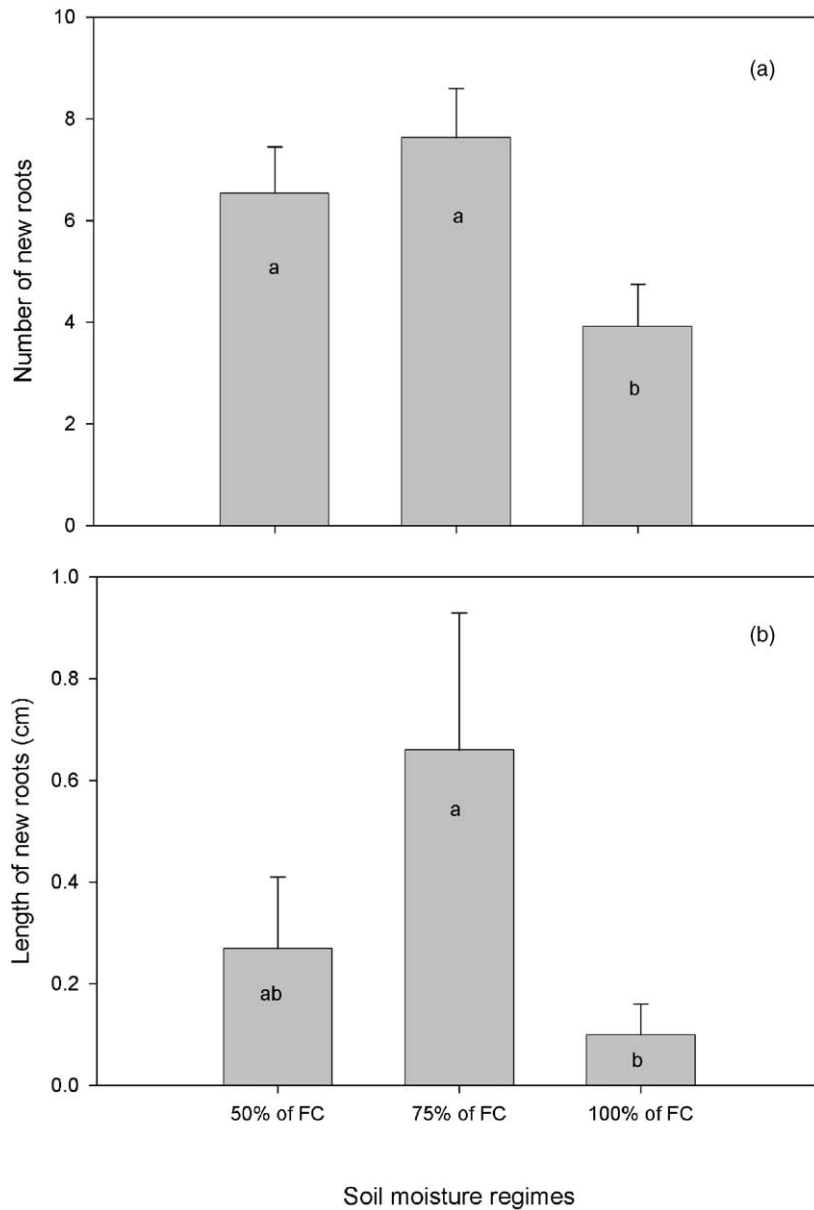


Fig. 1. Effect of soil moisture regimes (soil at 50, 75 and 100% of field capacity (FC), on root growth potential: (a) number of new roots and (b) length of new roots of narra transplants 7 days after transplanting. Means with the same letters are not significantly different at 5% level based on Duncan's new multiple range test.

The immediate response of narra to a drought condition could be attributed to the nature of its root system. Narra produces many lateral roots that increase its root area for water and nutrient uptake (Calora, 1992). Being a drought tolerant species, narra has a scattered root

system that is characterized by a larger root system sorption zone (Castaneto, 1997). New lateral roots developing under drought condition could significantly contribute to the ecophysiological function of the whole plant system (Gazal and Kubiske, 2004).

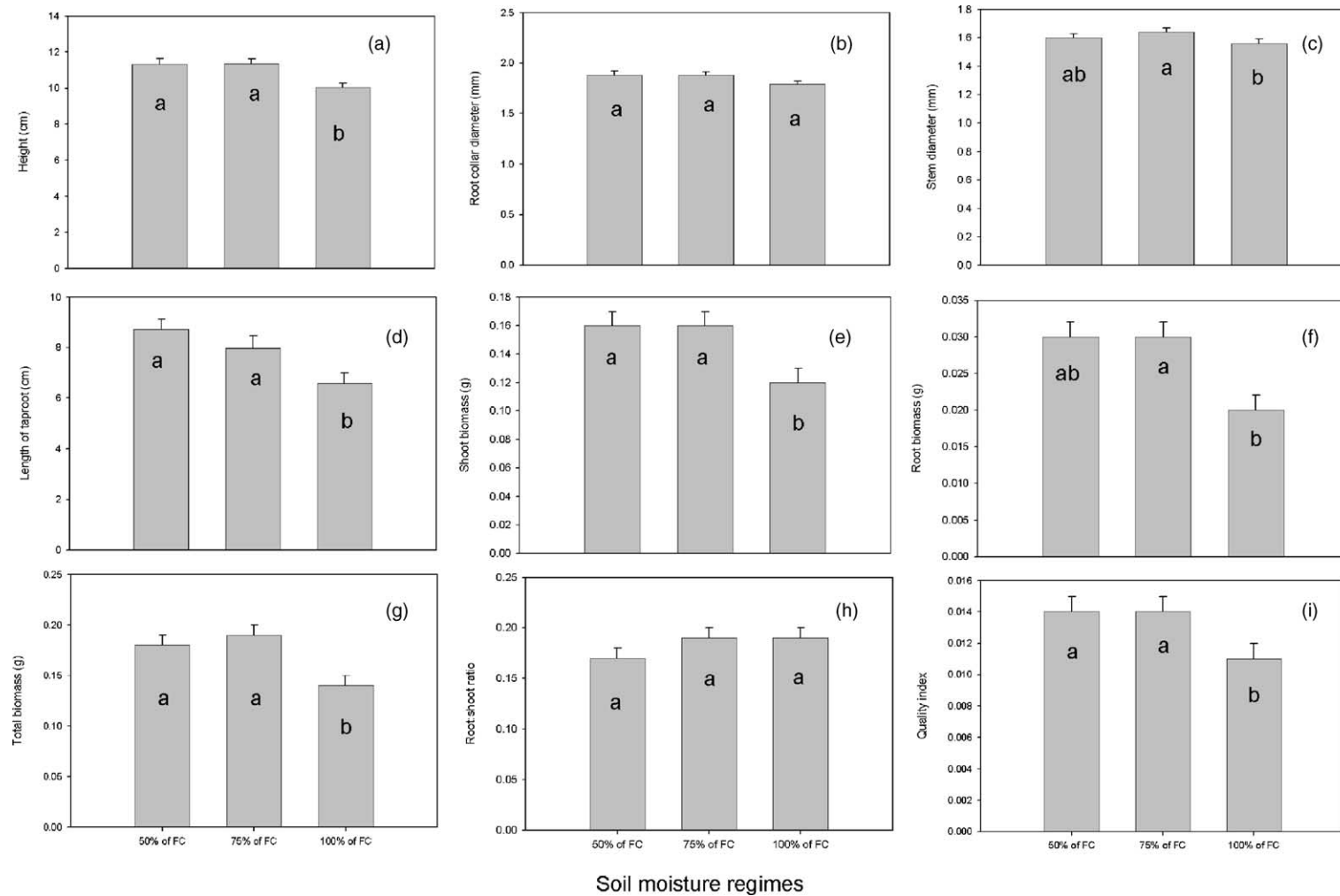


Fig. 2. Effect of soil moisture regimes (soil at 50, 75 and 100%) of field capacity (FC) on (a) height, (b) root-collar diameter, (c) stem diameter, (d) length of tap root, (e) shoot biomass, (f) root biomass, (g) total biomass, (h) root:shoot ratio, and (i) quality index of narra transplants. Means with the same letters are not significantly different at 5% level based on Duncan's new multiple range test.

It was consistently noticed that seedlings applied with the lowest amount of water (50% of field capacity) yielded a high number of new and longer roots. This was true in all the test periods considered in this study although it was only in the 7-day test period did moisture effect become significant. The initial reaction of the plants to inadequate moisture is to extend its root system quickly to supply the moisture needed for survival, establishment and subsequent growth. The density of absorbing roots strongly affects initial rate of water and nutrient uptake and competition among plants with roots in the same soil volume (Ludovici and Morris, 1996).

Root growth of Ponderosa pine in soil with 45 and 60% available water was the same or greater than in soil with 100% available water (Stone and Jenkinson, 1970). Ponderosa pine is a drought tolerant species capable of root growth in dry soil. This study confirmed that narra is capable of producing new roots in response to reduced soil moisture over a short period of time. High RGP is a sign that seedlings are at or near their seasonal peak of stress resistance (Ritchie and Tanaka, 1990). The presence of many root tips as indicated by high RGP also implies higher level of metabolic activity in plants (Abod and Simon, 1983).

Root growth potential is affected by morphology of the transplants particularly the fibrosity of the root system (Deans et al., 1990). Burdett (1979) found that RGP of *Pinus contorta* transplants was positively correlated to their root system fibrosity. Cannel et al. (1990) attributed the low RGP of Douglas-fir to their low root:shoot ratio and shorter root length. Root weight and diameter of loblolly pine were positively correlated with RGP (Williams et al., 1988), which is also similar in this experiment on narra seedlings. High seedling quality index was observed in narra seedlings under the low and medium moisture treatments (50 and 75% of field capacity). This suggests that narra transplants can attain a high quality index even in a condition where water is limiting. This result reaffirms that narra can perform well even in reduced soil moisture condition (50% of FC).

Plants have different responses to moisture stress condition depending on the length of the stress period. The significant response in height of narra transplants was only evident at the 14-day test period. This means that under moisture stress condition, height growth of narra would occur a week after it had initiated and

extended its roots for water and nutrient absorption. Once the condition becomes normal, root growth would then cease to give way to height growth. Water stress conditions resulted more carbon allocation to roots than to foliage (Gregory et al., 1997).

The result of the correlation analysis revealed that there was a positive and significant correlation of RGP with seedling height. Height of narra seedlings was positively affected by reduced soil moisture (50% of field capacity). Increased height in response to reduced soil moisture is considered a sound morphological trait attributed to high planting survival in the field (Tinus, 1996). Stem diameter is likewise used as a measure of performance of planted seedlings in the field. Slash pine seedlings with large root-collar diameter demonstrated greater survival (McGrath and Duryea, 1994). High survival rates of slash pine seedlings were achieved due to large root systems that promoted a more rapid recovery from transplanting shock by facilitating water and nutrient absorption.

5. Practical implication

Failure of many reforestation projects in the Philippines is primarily due to planting of poor quality seedling stocks and poor environmental and soil conditions of the land areas where the seedlings are planted. In such situation, careful selection and planting of only viable and vigorous seedlings are crucial to ensure high survival in the field. Thus, a simple and reliable nursery grading practice to monitor seedling quality is highly needed.

RGP measurement period for narra transplants need not be long since the 7-day test period is enough to generate meaningful results. This opportunity for shortening the test period is important in monitoring planting stock quality in the nursery prior to planting for reforestation or plantation establishment. The study looked into the quantity and quality of roots as seedling performance attributes that would supplement current grading practices for narra seedlings and other species. Future research should focus on RGP as another grading criterion to evaluate planting performance of narra in different site conditions. This will ensure the usefulness of RGP as a physiological parameter in assessing seedling growth and vigor before and after field planting.

The two methods of measuring RGP, such as counting the number of new roots and measuring their length are simple and easy to follow. As long as proper measurements are done, RGP can be successfully assessed by nursery staff. It is also cost-effective since it does not require special tools and equipment for reliable measurement.

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